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METHOD, APPARATUS AND USE

Technical field of the invention

The present invention generally relates to the field of providing substrates with viscous medium. More specifically, the invention relates to a method of providing a substrate with viscous medium, a corresponding apparatus, an apparatus for correcting application errors in connection with the application of viscous medium on a substrate, and use of jetting means for said correcting.

Background of the invention

In the field of electronics production, it is well known that possible sources of errors are the electronic circuit boards. Mainly, these errors originate from the application of viscous medium, e.g. solder paste, prior to the mounting of components on the board. Over the years, a number of different techniques have been proposed for detecting errors resulting from solder paste application. Originally, this detection was performed manually. Lately, however, the use of cameras in combination with image processing have become the preferred choice for detecting said errors. An example of this can be found in the Swedish Patent Application 9900124-0, which discloses a method and a device for contactless inspection of objects on a substrate.

When errors resulting from the application of solder paste have been detected, and preferably identified, appropriate action must ensue. Traditionally, a board containing errors as a result of the application of solder paste is simply taken out of the process. The removed board can then be discarded or, commonly, cleaned and subsequently reinstated at the beginning of the process. Recently, the results of the solder paste application, i.e. critical parameters thereof, are monitored and er-

rors are identified, and the monitored parameters are fed back so that appropriate measures can be taken. This is common in state-of-the-art screen printing applications.

This feedback can, in the simplest case, be a warning message when a parameter has crossed a certain preset limit. The operator can then decide which actions to take. On the other hand, an advanced system could incorporate artificial intelligence to adjust application parameters such as, in the case of screen printing, squeegee pressure, speed and angle, amount of paste on the stencil, cleaning interval, etc. Thus, critical process parameters can be monitored and adjusted so that the application errors can be reduced. However, the specific board containing the detected errors is dealt with in the traditional manner described above, i.e. the faulty board is removed from the entire process.

When using conventional dispensing, i.e. contact dispensing, as opposed to screen printing for the application of solder paste, dispensing heads with integrated measurement capabilities, for measuring the result of the application of solder paste, are known within the art. The measured parameters can be fed back for process control in order to reduce future errors. Since the integrated measurement capabilities can measure the solder paste application of a single dot, e.g. immediately following the dispensing of said dot, process parameters can be altered for the subsequent dispensing of dots on the same board. Thereby, small errors can be detected and process parameters adjusted so that, in the best case, major errors requiring the board to be removed from the process, can be avoided.

Summary of the invention

Thus, an object of the present invention is to provide a solution to the above-mentioned problems and to provide an improved production efficiency.

This and other objects are achieved according to the present invention by providing apparatus and a method having the features defined in the independent claims. Preferred embodiments are defined in the dependent
5 claims.

In general terms, the invention is based on the insight of the advantageous results that can be obtained by using correction measures in relation to the application of viscous medium on a substrate.

10 According to a first aspect of the invention, there is provided a method of providing a substrate with viscous medium, comprising the steps of applying said viscous medium onto the substrate, inspecting the results of said application, determining errors of the application
15 based on said inspection, and correcting at least some of said errors.

According to a second aspect of the invention there is provided a system or an apparatus for providing a substrate with a viscous medium, comprising application
20 means for applying the viscous medium onto the substrate, inspection means for inspecting the results of said application, processing means for determining application errors based on said inspection, and correction means for correcting at least some of said errors.

25 According to a third aspect of the invention there is provided an apparatus for correcting application errors in connection with application of a viscous medium on a substrate, said apparatus comprising processing means adapted to receive information of said errors in
30 the application of said viscous medium, and correction means for correcting at least some of said errors based on said information.

According to a fourth aspect of the present invention there is provided the use of jetting means for the
35 correction of application errors in regard to viscous medium provided on a substrate.

For the purposes of this application, it is to be noted that the term "viscous medium" should be interpreted as solder paste, flux, adhesive, conductive adhesive, or any other kind of medium used for fastening components on a substrate, or resistive paste; and that the term "substrate" should be interpreted as a printed circuit board (PCB), a substrate for ball grid arrays (BGA), chip scale packages (CSP), quad flat packages (QFP), and flip-chips or the like. It is also to be noted that the term "jetting" should be interpreted as a non-contact dispensing process that utilises a fluid jet to form and shoot droplets of a viscous medium from a jet nozzle onto a substrate, as compared to a contact dispensing process, such as "fluid wetting", which is the act of the viscous medium leaving the dispense tip, contacting and clinging to the substrate and remaining on the substrate as the dispense tip pulls away.

Preferably, use is made of jetting and/or removing means for the correction of errors resulting from the application of a viscous medium on a substrate. Said correction is performed after the application of said viscous medium, but prior to any soldering thereof. Preferably, said correction is also performed prior to the mounting of components, at the locations on the substrate where correction is required. It must, however, be noted that the correction of said errors can be performed after mounting of components at other locations on the substrate. This is for instance the case when mounting components on both sides of a substrate. Then, correction of errors according to the present application can be performed at one side after components have been mounted and attached to the other side of the substrate.

Thus, the correction of viscous medium applied on a substrate according to the present invention must not be mistaken for the known correction of soldered connections, which is performed late in the component mounting cycle after the mounting of components and hardening of

the viscous medium, i.e. reflow of solder paste, used for mechanically and electrically connecting the component to the substrate. An advantage of correcting errors prior to the mounting of components and hardening of the viscous medium is that it is much cheaper, as compared to making corrections late in the mounting process cycle. This is due to the fact that valuable production capacity is not occupied by a substrate that must be corrected. Further, correction performed prior to the mounting of components is easier and requires less correction steps.

According to the present invention, said application of viscous medium is not intended to be limited to a particular method of applying viscous medium, i.e. application through e.g. screen printing, conventional dispensing, jetting, etc. On the contrary, the present invention is intended to be applicable for the correction of any substrate that is provided with a viscous medium, regardless of how the viscous medium was originally applied.

According to one embodiment of the present invention, following the application of viscous medium on a substrate, the result of said application is inspected. This inspection can be performed after the completion of the application of viscous medium on the entire substrate, or can be performed during said application, e.g. at intermittent intervals or continuously, depending on the application method being used. When applying the viscous medium through screen printing, the inspection is preferably performed when the application is completed. When applying viscous medium through contact dispensing or jetting, the inspection can be performed following the dispensing of viscous medium at each specific site or position, or at certain predetermined intervals.

The inspection not only detects whether a site or position has been provided with viscous medium, but also detects whether the correct amount, i.e. volume, of viscous medium has been applied, whether the position of the applied medium is correct, or within a predetermined

fault range, and has the correct shape and height at a given position. The term "correct" has here the meaning of the measured parameter being within a fault range that is predetermined.

5 According to alternative embodiments of the invention, the inspection could involve inspection of the entire substrate, all locations on the substrate where viscous medium is to be applied, or only specific locations on the substrate. The latter would preferably involve inspecting specific locations that are particularly error prone, e.g. locations where components are later to be placed which are particularly sensitive to errors in the applied viscous medium, such as components having leads with a very fine pitch, or components which are difficult to inspect after soldering, such as BGA components.

15 According to an embodiment of the invention, following the detection of an error, the characteristics of said detected error are determined and stored. Preferably, the error characteristics are further analysed and evaluated to determine whether the error needs correcting. If so, the proper method of correcting said error is also determined. According to an embodiment, the time needed for performing said correction is estimated and stored.

25 According to an embodiment of the invention, the application of viscous medium is performed through screen printing. Following the completion of the screen printing, the result of the screen printing is inspected and any errors are detected, determined, and analysed. The results of said inspection can be fed back to the screen printer for enabling the screen printer to correct or adjust parameters. Following the inspection and determination of errors, correction of the determined errors ensues.

30 According to another embodiment of the invention, the application of viscous medium is performed using conventional contact dispensing or jetting. This enables

continuous, on-line inspection of the results of said application. Thus, the application of viscous medium at a single location can be immediately inspected, e.g. dot by dot, and the results can both be fed back for adjustment of dispensing or jetting parameters, or can be immediately transferred to means for correcting any detected errors. According to an alternative embodiment, the inspection is performed following the completion of the application of viscous medium on the entire substrate.

10 Then, and as described above, the inspection could involve inspecting the entire substrate, all locations on the substrate where viscous medium is to be applied, or predetermined specific locations on the substrate.

According to the present invention, the correction of determined errors on a substrate is performed by the use of jetting for applying additional viscous medium. Not only will jetting additional viscous medium onto the substrate overcome the shortcomings of the conventional dispensing as discussed above, jetting is also faster, more accurate, and more flexible in comparison to screen printing as well as conventional dispensing. The use of conventional dispensing often provide a bottle neck that increases the cycle time in the overall component mounting process, as compared to the use of jetting. It has also been found that it is possible to achieve smaller dots when using jetting than when using conventional dispensing. Further, by using jetting, it is possible to apply dots of viscous medium having differing heights, which is hardly possible when using screen printing.

30 However, at positions where it has been determined that there has been applied too much viscous medium, the surplus viscous medium must be removed. This is performed according to an embodiment of the invention by the provision of removing means capable of removing viscous medium from a specific location on the board. Said removal is preferably performed through suction of the viscous medium. Due to the characteristics of the viscous medium,

e.g. solder paste, the remains on the substrate of viscous medium at a location at which removal of the viscous medium has been performed is generally minute. But, there may be some flux remains left at said locations. However, this is not a problem due to the fact that where cleaning of the substrate is performed following the soldering of components, in order to get rid of deleterious flux that is used when mounting the components, said flux remains will be removed during said cleaning; and in cases where it is not necessary to remove flux following said soldering, the flux remains will not be a problem. Thus, additional cleaning of the substrate following the removal of surplus viscous medium will not be necessary.

The combination of jetting means and removing means for correcting errors on a substrate provided with viscous medium enables correction of all types of application errors. These errors may for instance include applying a surplus of or insufficient viscous medium or insufficient at a given position, applying viscous medium at wrong positions, applying viscous medium where the result of the application is misaligned, applying viscous medium having characteristics deficiencies of some sort, etc.

According to an embodiment of the present invention, the correction of errors is performed in a separate machine, i.e. the substrate is forwarded to the correction machine following the determination that correction of the result of viscous medium application is required. According to an alternative embodiment, the correction machine also comprises the inspection means described above. Then, all substrates are forwarded to the correction machine for inspection and possible correction of detected errors. Preferably, the results of said inspection are fed back to the machine for allowing adjustment of application parameters.

Said embodiment of having a stand alone correction machine is particularly useful when the initial application of viscous medium is performed by screen printing or

contact dispensing. Then, the advantages relating to screen printing and contact dispensing, as recognised by the man skilled in the art and not further described herein, can be combined with the above described advantages of correction of errors through jetting.

According to an alternative embodiment of the invention, the correction means, i.e. jetting means for correction and removing means, are integrated in the machine for performing the initial application of viscous medium onto the substrate. Thus, the inspection can be performed continuously and any correction of the substrate necessary can be done instantly.

Said embodiment of having an integrated machine for both the initial application of viscous medium and the ensuing inspection and correction is particularly useful when the initial application of viscous medium is performed by jetting. Thus, a single jetting means can be utilised for both the initial application and the correction. This would facilitate the construction of the machine and minimise the size of the machine and also would provide a small footprint, i.e. the overall floor space required for the machine. Alternatively, the correction is performed by a separate jetting means not used for the initial application of viscous medium. This would decrease the overall time required for the application and the possible correction.

Generally, a separate machine for the correction, and possibly also for the inspection, would increase line length but decrease the overall cycle time for each substrate as compared to an integrated machine as described above incorporating both the initial application of viscous medium and the subsequent or concurrent correction. Further, an integrated machine where the initial application is performed through screen printing or contact dispensing would have to overcome a number of constructional difficulties.

According to a specific embodiment of the present invention, all errors occurring on a single substrate following the completion of the application of viscous medium, e.g. following screen printing, are jointly analysed and the total amount of corrections needed for the entire substrate is then determined. Thus, it can be determined whether the sum of errors are so great that correction of the errors on the substrate are not worthwhile. Preferably, it has been determined the time required for error correction of each detected error requiring correction, then the overall correction time for the entire substrate is evaluated. If it is found that correction of the errors on the substrate if not worthwhile, the substrate can be removed from the process and cleaned without any corrections being made.

Thus, the use of jetting for correcting errors resulting from the application of viscous medium onto a substrate enables not only error prevention, which is known through the feedback of inspection results, but also error correction. This guarantees that a low defect level can be maintained, which in turn results in the main source of failures in the electronics production is overcome, reducing the production costs considerably. This is done without more than a fractional addition of time required for the overall application of viscous medium on a substrate.

The above mentioned and other aspects, advantages, and features of the invention will be more fully understood from the following description of exemplifying embodiments thereof.

Brief description of the drawings

Exemplifying embodiments of the invention will be described below with reference to the accompanying drawings, in which:

Fig. 1 is a block diagram illustrating a typical prior art arrangement for handling errors resulting from application of viscous medium.

Figs 2-5 are block diagrams illustrating arrangements according to alternative embodiments of the present invention.

Figs 6-11 are flow charts illustrating alternative embodiments of the method according to the present invention.

10

Detailed description of preferred embodiments

In the block diagrams of Figs 1-5, the thick-lined arrows depict the movement of a substrate through the production line. The dashed boxes simply indicate that the means or apparatus depicted within the box can be incorporated in a single machine.

With reference to Figs 2-11, there is illustrated exemplary embodiments of the present invention. As to the means used for applying solder paste, inspecting the results of said application, removing solder paste, and component mounting, use can be made of means which by themselves are known within the art, and the constructional features of which are also known. Therefore, a constructional and functional description of each separate means has been omitted.

With reference to Fig. 1 there is shown a typical prior art arrangement for handling errors resulting from solder paste application. The solid arrows depict the transportation of a substrate through the arrangement. The substrate is first brought to a machine 2 for application of the solder paste. Following the application of solder paste, the substrate is brought to an inspection means 3 where the result of the application is inspected. When the application is performed through contact dispensing or jetting, the inspection could take place simultaneously with the application. Then, of course, the application means 2 and the inspection means 3 are incor-

porated in a single machine 1. If the inspection shows that the result of the solder paste application is satisfactory, then the substrate is conveyed to a component mounting machine 5. If not, then the substrate is taken
5 out of the production line, either discarded cleaned in a cleaning machine 4 and reinstated in the production line prior to the application machine 2.

There will now be described with reference to Figs 1 and 6, a first embodiment of the present invention for
10 correcting errors resulting from solder paste application. A substrate is first brought to an application and inspection machine 10, incorporating both application means 12 and inspection means 14. A conventional method of application is used and therefore not further de-
15 scribed. As can be seen from the flow chart in Fig. 6, solder paste is applied to the substrate at 102. Then the inspection of the application result commences at 104 by indicating the starting point for the inspection. The solder paste application is inspected for a position N at
20 106. At 108, it is determined whether an error is detected for position N and, if so, the parameters of the detected error, e.g. size of solder paste dot, dot position, dot shape, etc., is recorded and, possibly, also fed back to the application means at 109. At 110, there
25 is a check whether all positions to be inspected have been inspected. If not, the position parameter N is incremented and the next position is inspected at 106.

Following the inspection for all selected positions, the parameters are evaluated at 112 to determine whether
30 correction of the substrate is required. If not, the substrate is transferred at 113 to a component mounting machine 18. However, if correction is required, then the total amount of correction needed is calculated at 114. The result of this calculation is defined as a correction
35 value, which at 116 is compared to a threshold value for determining whether correction of the substrate is worthwhile. That is, if there are vast correction actions re-

quired, then it might be more economical to simply discard the substrate. This is of course dependent on the type of substrate and the cost involved for the substrate. If correction is deemed worthwhile, then the substrate is transferred at 118 to a correction machine 16. The correction machine 16 incorporates both means for removing surplus solder paste, as well as jetting means for jetting additional solder paste onto the substrate.

As is understood by the man skilled in the art, the above-mentioned steps of recording, evaluating, determining and sending and retrieving information can be performed by the use of conventional processing means (not shown).

Turning now to figs 3 and 7, there is illustrated a second exemplary embodiment of the present invention. The invention according to this embodiment differs from the first embodiment in that the application means 22 is not incorporated with the inspection means 24. Instead, the inspection means 24 can be incorporated with correction means 26 in a combined inspection and correction machine 20. As is shown in the flow chart of Fig. 7, in this exemplary method 200 the substrate is transferred to the application means 22 at 202 and provided with solder paste. Then, the substrate is at 204 transferred to the inspection and correction machine 20. The inspection means 24 inspects at 208 the solder paste application result for position N.

At 210 it is determined whether the inspection for position N reveals that an error that require correction is detected. If so, the error is corrected by the correction means 26 at step 211. At 212 it is checked whether all positions have been inspected. If so, the substrate is transferred at 214 to the component mounting machine 18. For ease of description, it is indicated in Fig. 7 that the correction for position N is performed directly following the inspection for position N.

However, the inspection means 24 might perform an inspection faster than the correction means 26 can perform the corresponding correction. In reality, the inspection is performed as fast as possible, and the information as to which positions require correction, and which correction that is needed, is continuously transmitted to the correction means 26. Thus, the inspection means 24 does not wait at a specific position for the correction means to finish correcting at that position. This applies equally for the embodiment of Figs 5 and 11, which will follow.

Turning now to Figs 4 and 5, there is shown two alternative embodiments where the initial application of solder paste is performed with jetting means 32, 40. In the embodiment of Fig. 4, there are provided two separate jetting means, one for the initial solder paste application, and one included in the correction means 36 for the correctional jetting of additional solder paste. In the embodiment of Fig. 5, the same jetting means is used for both the initial solder paste application, and for the correctional jetting of additional solder paste. Thus, the application, inspection and correction means are all integrated in one machine 40.

The method 300 for the arrangement illustrated by Figs 4, 8 and 9 differs from the methods of Figs 6 and 7 in that the application for each position can be essentially immediately inspected. Turning to Figs 8 and 9, solder paste is applied through jetting means 32 for position N at step 304. The result of the application is then inspected by the inspection means 34 at step 306. If correction is required, determined at 308, the correction parameters is relayed to the correction means 36 at step 309. The application and inspection then continues at 304 and 306 until solder paste have been applied and the inspection have been performed for all positions, determined at 310. Simultaneously with said application and inspection, the correction means 36 performs correction

of the detected errors at 322 based on information received at 320. After each correction has been completed, a signal indicative thereof is transmitted at step 324 to processing means (not shown). At step 310, it is also determined whether all corrections have been completed before the substrate is transferred to the component placement machine 18 at step 312.

Turning finally to Figs 5, 10 and 11, there are illustrated two alternative methods 400, 500 according to alternative embodiments of the present invention. As described above, a single jetting means is used for both the initial application of solder paste and the subsequent possible corrective jetting of additional solder paste. In Fig. 10 there is shown an alternative where the corrective jetting is performed following the completion of the initial application, whereas in Fig. 11 there is shown an alternative where the jetting correction is performed as soon as an error has been detected. As obvious to the man skilled in the art, any combination of these two alternatives is also possible.

The initial steps 402-410 of method 400 correspond closely to the initial steps 102-110 of method 100, as shown in Fig. 6. However, following the completion of the initial solder paste application and the inspection and recording of errors, correction of the detected errors is performed by the correction means, both where additional jetting is required as well as the removal of solder paste. According to Fig. 10, for ease of illustration, this is performed by resetting the position parameter N, at 412 and looping through all positions on the substrate and correcting them in order, at 414-420. However, any type of correction algorithm can be used. Finally, the substrate is transferred at 422 to the component mounting machine 18.

The method 500 shown in Fig. 11 correspond to the method 300 of Fig. 8 for all steps 502-512, except for step 509. In method 500 the required correction is per-

formed at step 509, whereas at step 309 of the method
300, parameters are transmitted to separate correction
means. However, as stated above, the correction for a
specific position does not necessarily take place immedi-
5 ately following the inspection of that position.

Even though the invention has been described
above using exemplifying embodiments thereof, altera-
tions, modifications and combinations thereof, as under-
stood by those skilled in the art, may be made within the
10 scope of the invention, which is defined by the accompa-
nying claims.

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CLAIMS

1. A method of providing a substrate with viscous
 5 medium, comprising the steps of
 applying said viscous medium onto the substrate,
 inspecting the results of said application,
 determining errors of the application based on said
 inspection, and
 10 correcting at least some of said errors.

2. The method as claimed in claim 1, wherein the
 step of determining errors comprises the step of evaluat-
 ing all of the determined errors and deciding to what ex-
 15 tent the determined errors shall be corrected.

3. The method according to claim 1 or 2, wherein the
 step of determining errors further comprises the step of
 evaluating each of the determined errors and deciding on
 20 proper corrective action.

4. The method according to claim 3, wherein the step
 of determining errors comprises the steps of
 estimating for each of the determined errors the
 25 time required for performing said corrective action, and
 calculating the overall time required for corrective
 action of all determined errors.

5. The method according to any previous claims,
 30 wherein said correction comprises jetting of additional
 viscous medium onto the substrate and/or removing viscous
 medium from the substrate.

6. The method according to claim 5, wherein the step
 35 of correcting comprises the step of removing viscous me-
 dium from positions on the substrate where viscous medium
 has been unintentionally applied.

7. The method according to claim 5 or 6, wherein the step of correcting comprises the step of removing surplus viscous medium from positions on the substrate where more
5 viscous medium has been applied than intended.

8. The method according to any one of claims 5-7, wherein the step of correcting comprises the step of jetting of additional viscous medium to positions on the
10 substrate where no viscous medium has been applied even though intended.

9. The method according to any one of claims 5-8, wherein the step of correcting comprises the step of jetting of additional viscous medium to positions on the
15 substrate where the amount of applied viscous medium is insufficient.

10. The method according to claim 8 or 9, further
20 comprising the steps of
inspecting the results of said jetting of additional viscous medium,
determining errors of said jetting of additional viscous medium based on said inspection, and
25 correcting at least some of said errors.

11. The method according to any one of the previous claims, wherein the step of applying a viscous medium is performed by jetting.

12. The method according to any one of claims 5-10, wherein the step of applying a viscous medium is performed by jetting and wherein the application of the viscous medium and the jetting of additional viscous medium
35 is performed by the same jetting means.

13. The method according to any one of claims 1-10, wherein the step of applying a viscous medium is performed by screen printing.

5 14. The method according to any one of claims 1-10, wherein the step of applying a viscous medium is performed by contact dispensing.

10 15. The method according to any one of the previous claims, wherein said step of correcting is performed after said step of applying viscous medium has been completed.

15 16. The method according to any one of the previous claims, wherein said step of inspecting is performed after said step of applying viscous medium has been completed.

20 17. The method according to any one of claims 1-14, wherein said step of correcting is performed simultaneously with said step of applying viscous medium.

25 18. The method according to any one of claims 1-15 or 17, wherein said step of inspecting is performed simultaneously with said step of applying viscous medium.

30 19. An apparatus for providing a substrate with a viscous medium, comprising
application means for applying the viscous medium
onto the substrate,
inspection means for inspecting the results of said application,
processing means for determining application errors based on said inspection, and
35 correction means for correcting at least some of said errors.

20. The apparatus according to claim 19, wherein the processing means comprises evaluating means for evaluating each of the determined errors and deciding to what extent the determined errors shall be corrected.

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21. The apparatus according to claim 19 or 20, wherein said correction means comprises jetting means for jetting of additional viscous medium onto the substrate and/or removing means for removing surplus viscous medium from the substrate.

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22. The apparatus according to any one of claims 19-21, wherein said application means is a jetting means.

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23. The apparatus according to any one of claims 19-21, wherein said application means is a jetting means and wherein said application means and said jetting means for jetting of additional viscous medium is the same jetting means.

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24. The apparatus according to any one of claims 19-21, wherein said application means is a screen printing means.

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25. The apparatus according to any one of claims 19-21, wherein said application means is a contact dispensing means.

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26. An apparatus for correcting application errors in connection with application of a viscous medium on a substrate, said apparatus comprising

processing means adapted to receive information of said errors in the application of said viscous medium, and

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correction means for correcting at least some of said errors based on said information.

27. The apparatus according to claim 26, further comprising inspection means for inspecting the results of said application, wherein said processing means receives said information from said inspection means.

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28. The apparatus according to claim 26 or 27, wherein the processing means comprises evaluating means for evaluating each of the determined errors.

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29. The apparatus according to any one of claims 26-28, wherein said correction means comprises jetting means for jetting of additional viscous medium onto the substrate and/or removing means for removing surplus viscous medium from the substrate

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30. Use of jetting means for the correction of application errors in regard to viscous medium provided on a substrate.

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ABSTRACT

Solder paste application, inspection and correction.

5 Following or during application of solder paste on a substrate, the result thereof is inspected and any detected errors are registered. Following an evaluation as to whether correction of these errors is required and if it would be worthwhile, the errors are corrected. The correction involves removing solder paste from locations

10 where so required, and jetting of additional solder paste to locations where so required.

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1/7

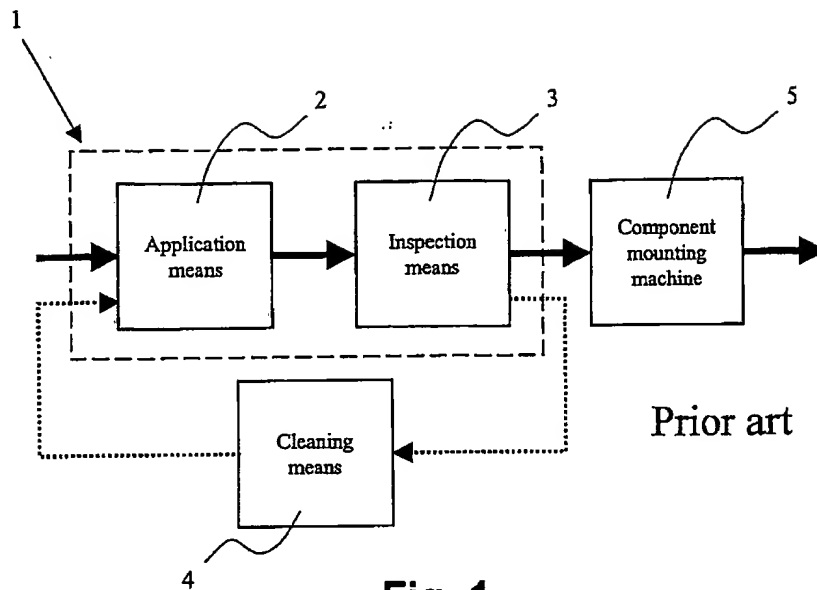


Fig. 1

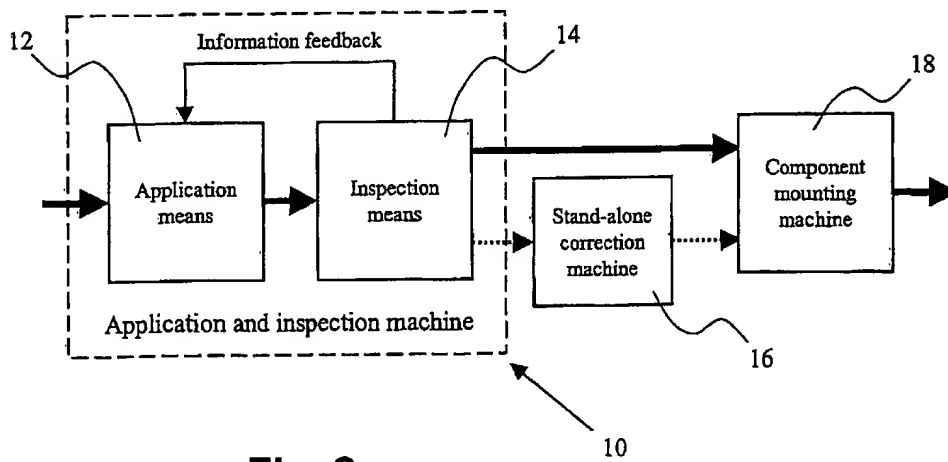


Fig. 2

2/7

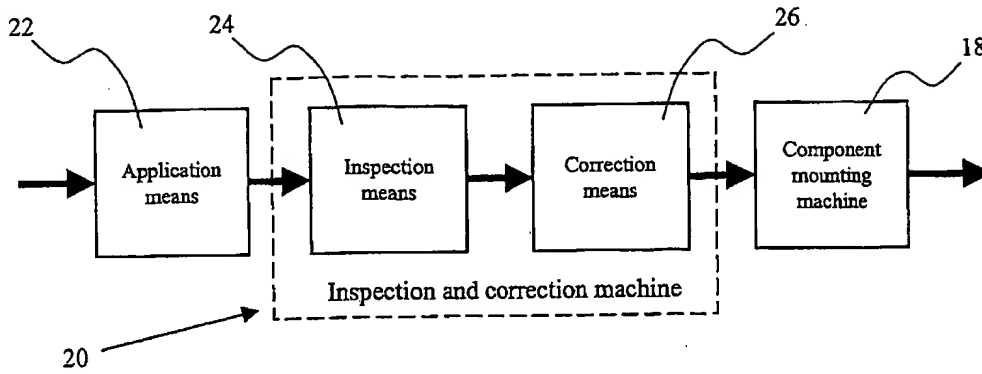


Fig. 3

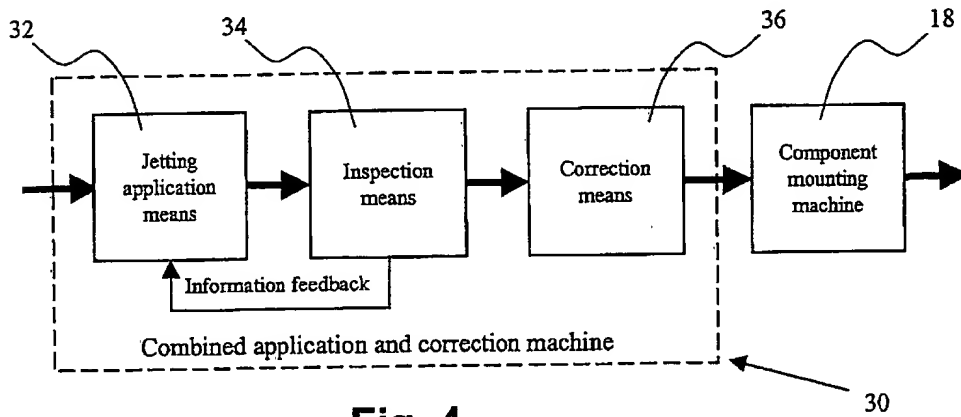


Fig. 4

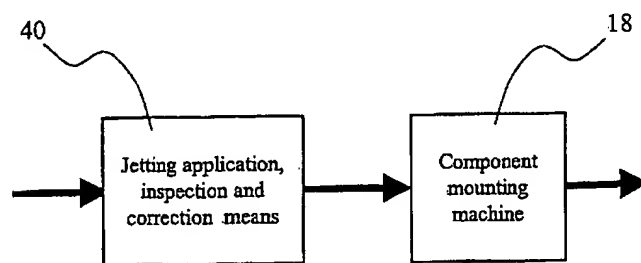


Fig. 5

3/7

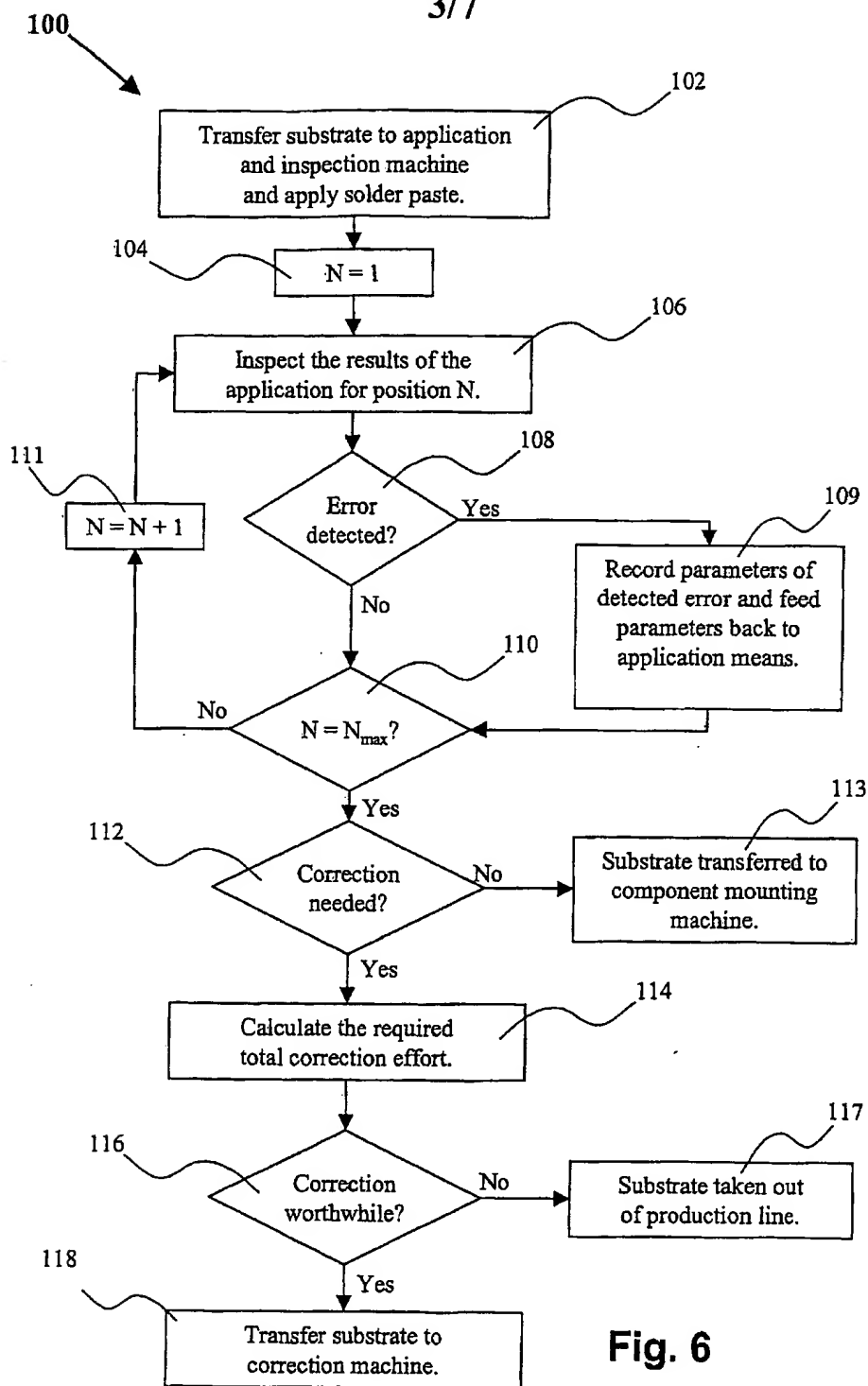


Fig. 6



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4/7

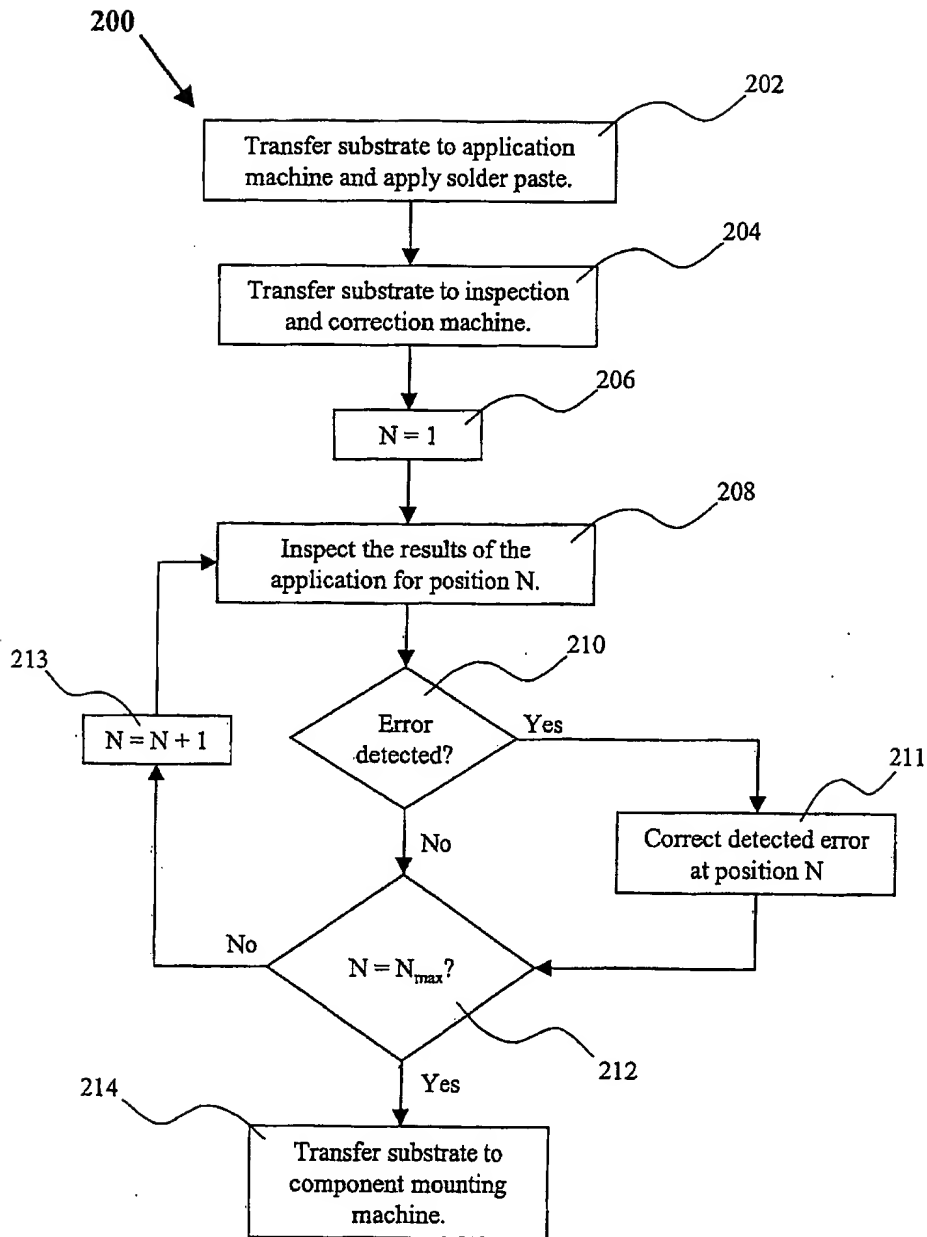


Fig. 7

5/7

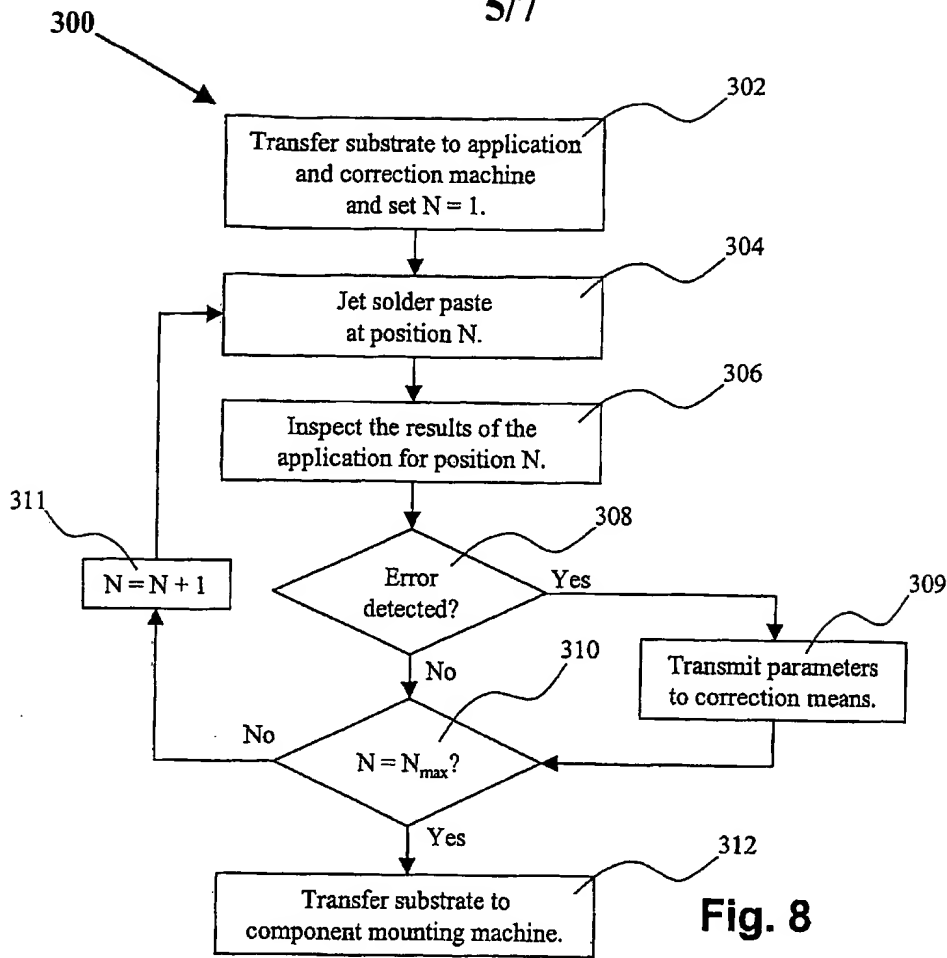


Fig. 8

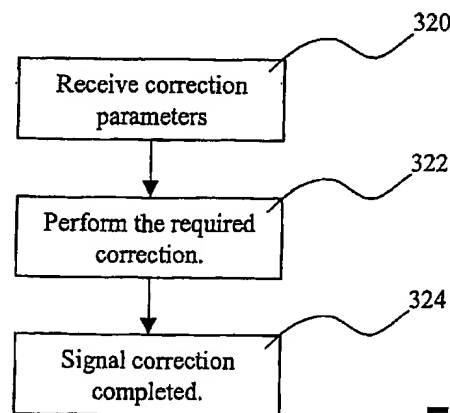


Fig. 9

6/7

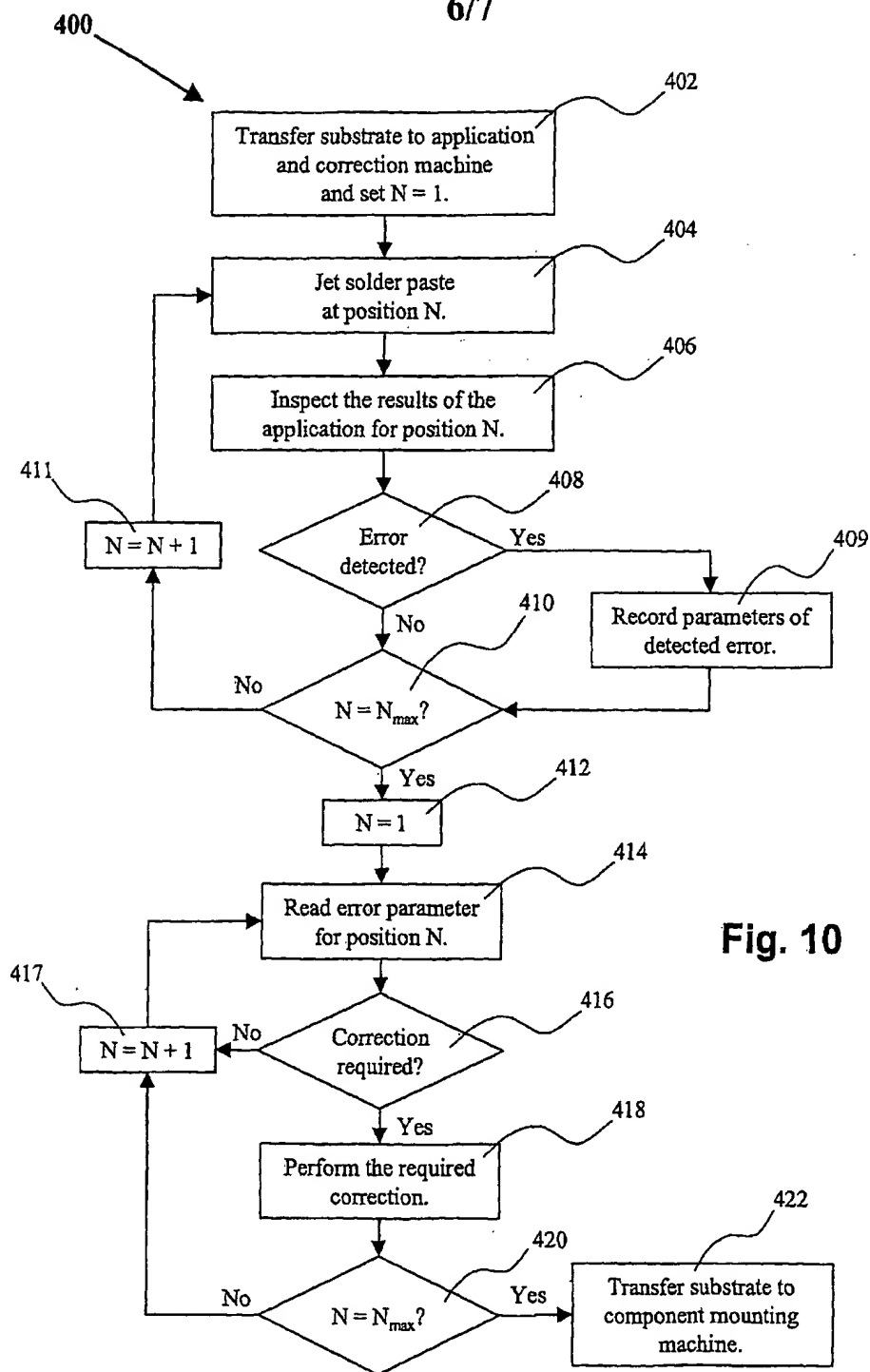


Fig. 10

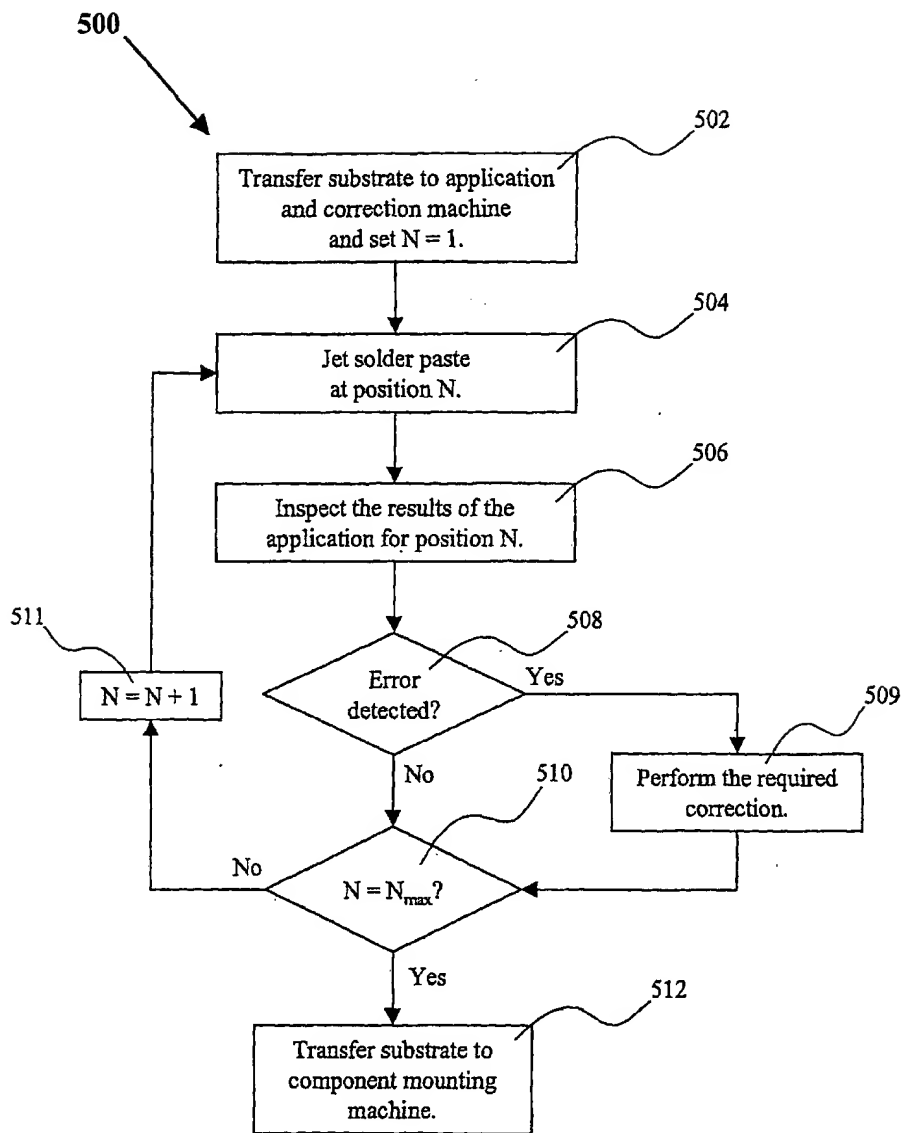


Fig. 11

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